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NUTRITION OF OYSTERS: THE NATURE OF THE SO-CALLED "FATTENING" OF OYSTERS.

By PHILIP H. MITCHELL.

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INTRODUCTION.

The term "fat" as applied to oysters refers in a popular sense to their appearance. When in that condition the meats look plump and have in the body portions a milky appearance not unlike emulsified fat. The juice running out of the meats, however, shows the opalescence characteristic of glycogen solutions. This, together with the fact that glycogen is shown by analysis to be especially abundant in some specimens of oysters and to vary greatly in different specimens, suggest the possibility that glycogen may be the chief if not the only substance increased in oysters when they become "fat."

In a previous paper[a] it was shown that glycogen shows seasonal variations in oysters and that an increase of glycogen accompanies favorable feeding conditions. It was also shown that glycogen storage not only accompanied the normal feeding process, but could occur as the result of assimilation of sugar in solution in the water utilized by oysters.

This paper presents evidence in the form of chemical analyses[b] of oysters in varying nutritive conditions to show that the amount of glycogen present is the only material which marks a notable difference between "fat" and "lean" oysters.

VARIATIONS OF PROTEIN IN THE OYSTER COMPARED WITH THOSE OF GLYCOGEN.

The percentage of glycogen or protein in whole oyster meats is not a useful index as to their nutritive condition or their value as human food. The great variations in the proportion of water present in oysters are obvious causes of apparent variations in other constituents when figured as percentages. It goes almost without saying that the results of analyses must be expressed in terms of percentage of dry substance. An equally important variable is the salt content. Ash determinations made under comparable conditions have shown in these analyses variations from 14 to 37 per cent of the dried weight. It is therefore necessary in comparing determinations of glycogen,

[a] "Nutrition of oysters: Glycogen formation and storage," Bull. Bureau of Fisheries, vol. xxxv, 1915–16, pp. 151–161.

[b] Part of the analytical work presented in this paper was done by A. E. Barnard.

protein, etc., in oysters to express results in terms of percentage content of the ash-free solids. Glycogen and nitrogen, the latter to be used as an index of the amount of protein, were determined in many specimens of oysters of varying nutritive conditions. Some oysters were analyzed immediately after removal from their natural habitat, others after treatment in various artificial ways.

The results of a series of analyses are given in Table 1. The arrangement is in decreasing order of the amounts of glycogen in the ash-free solids.

TABLE 1.—COMPARISON OF THE GLYCOGEN AND NITROGEN CONTENT OF OYSTER MEATS.

Experiment No.	Dried meats.			Ash-free solids.		Experiment No.	Dried meats.			Ash-free solids.	
	Glycogen content.	Nitrogen content.	Ash content.	Glycogen content.	Nitrogen content.		Glycogen content.	Nitrogen content.	Ash content.	Glycogen content.	Nitrogen content.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	18.55	7.31	17.40	22.46	8.86	17	7.44	8.80	28.64	10.45	12.33
2	17.61	7.98	19.10	21.76	9.87	18	6.19	7.86	35.70	9.63	12.22
3	12.51	8.61	21.20	15.88	10.93	19	6.07	7.86	32.15	8.94	11.61
4	10.54	7.92	29.30	14.89	11.20	20	6.17	8.21	30.22	8.83	11.78
5	10.51	8.04	28.94	14.79	11.20	21	5.07	8.08	33.52	7.63	12.17
6	9.90	7.50	33.00	14.76	11.20	22	4.85	8.05	34.20	7.38	12.22
7	10.56	7.96	27.78	14.61	11.03	23	5.37	9.03	26.40	7.29	12.26
8	9.18	7.17	35.42	14.22	11.10	24	5.02	8.19	30.60	7.25	11.82
9	10.65	8.82	23.30	13.91	11.50	25	4.55	7.46	35.75	7.09	11.62
10	10.80	9.28	21.97	13.85	11.90	26	4.03	7.58	37.72	6.49	12.17
11	8.69	7.13	35.60	13.51	11.08	27	4.20	8.04	34.20	6.40	12.22
12	10.76	9.20	19.50	13.38	11.42	28	4.34	8.76	30.30	6.23	12.57
13	8.76	7.96	27.55	12.10	11.00	29	3.78	7.73	35.60	5.88	12.02
14	9.26	9.03	21.38	11.77	11.48	30	3.51	7.48	37.60	5.64	12.01
15	7.59	7.32	34.00	11.50	11.10	31	3.82	8.76	31.62	5.59	12.11
16	7.85	8.65	29.41	11.11	12.24	32	1.93	8.02	36.75	3.05	12.69

Examination of Table 1 shows that as the percentage of glycogen in the ash-free solids decreases the percentage of nitrogen, similarly computed, tends to increase. There is not a regular mathematical relationship between the two sets of figures, but many of the irregularities would fall within the limits of experimental errors. At any rate, the series shows strikingly that protein, as indicated by nitrogen determinations, does not increase in oysters as an accompaniment to glycogen storage.

In spite of their long continued growth, oysters, indeed, have some tendency toward nitrogen equilibrium. Like the higher animals, oysters not only store glycogen in preference to protein when food is plentiful, but also use glycogen to protect themselves from loss of body protein when food is scarce. Evidence of this is shown by a more detailed examination of some of the results recorded in this table. Eleven of these results are segregated in Table 2. They were selected because in each case previous experiments, recorded in the first paper[a] of this series, showed that changes in glycogen amounting to 10 per cent or more had occurred in periods from 2 to 14 days. The various abnormal feeding conditions causing these sudden fluctuations in glycogen content are explained in Table 2.

That the comparatively small variations in the nitrogen percentages in ash-free solids are merely due to the glycogen fluctuations can be seen from the computations of the percentage of nitrogen figured not only on an ash-free but also glycogen-free basis. These results are sufficiently uniform to show that sudden variations in the food supply of oysters are not accompanied by changes in their protein content.

[a] "Nutrition of oysters: Glycogen formation and storage," Bull. Bureau of Fisheries, vol. XXXV, 1915–16, pp. 151–161.

TABLE 2.—COMPARISON OF GLYCOGEN AND NITROGEN OF OYSTERS WHICH SHOW SUDDEN CHANGES IN GLYCOGEN DUE TO ABNORMAL FEEDING CONDITIONS.

Experiment No.	Treatment.	Ash-free solids.		
		Glycogen content.	Nitrogen content.	Nitrogen in ash-free and glycogen-free solids.
		Per cent.	*Per cent.*	*Per cent.*
6	Fed dextrose	14.76	11.20	13.15
7	.....do	14.61	11.03	12.94
8	Fed chopped seaweeds	14.22	11.10	12.95
9	Starved in filtered water	13.91	11.50	13.35
11	Starved in partly purified water	13.51	11.08	12.81
19	Fed dextrose	8.94	11.61	12.75
20	.....do	8.83	11.78	12.92
21	.....do	7.63	12.17	13.16
28	In polluted water 4 days	6.23	12.57	13.40
31	Changed from salt to fresh water	5.59	12.11	12.84
32	In polluted water 14 days	3.05	12.69	13.09

Changes in the proportion of protein present, aside from the uniform increase due to growth, no doubt occur in the oyster. An instance is shown by examination of certain of these results. Those in Table 3, chosen because they represent analyses made very soon after the oysters were taken from their natural habitat, show marked differences in their nitrogen content. This is true even when figured on a glycogen-free basis. That seasonal changes are responsible for this is indicated by the fact that oysters taken in July and August, which include the spawning season, tend to show a higher proportion of nitrogen than those taken in November. Further work would be required to give an adequate explanation of this, but the suggestion that accumulation of egg and sperm materials, together with heightened metabolism of reproductive glands, may be the explanation is obvious.

TABLE 3.—COMPARISON OF GLYCOGEN AND NITROGEN OF OYSTERS WHICH HAD NOT BEEN SUBJECTED TO ABNORMAL EXPERIMENTAL CONDITIONS.

Experiment No.	Date when taken from water.	Ash-free solids.			Experiment No.	Date when taken from water.	Ash-free solids.		
		Glycogen content.	Nitrogen content.	Nitrogen in ash-free and glycogen-free solids.			Glycogen content.	Nitrogen content.	Nitrogen in ash-free and glycogen-free solids.
		Per cent.	*Per cent.*	*Per cent.*			*Per cent.*	*Per cent.*	*Per cent.*
1	Nov. 15	22.52	8.86	11.46	25	July 27	7.09	11.62	12.54
2	Nov. 15	21.65	9.87	12.60	26	July 29	6.49	12.17	13.00
4	Aug. 20	14.89	11.20	13.17	27	July 19	6.40	12.24	13.08
16	Aug. 7	11.11	12.24	13.76	29	July 20	5.86	12.02	12.79
18	Aug. 10	9.63	12.22	13.53	30	July 22	5.64	12.00	12.72
22	July 7	7.29	12.22	13.17					

VARIATIONS OF FAT IN THE OYSTER COMPARED WITH THOSE OF GLYCOGEN.

The storage of fat in oysters, as detected by ether extraction of the dried meats, was also investigated. In the previous paper [a] the suggestion that fat might be formed from dextrose was tentatively made. It was based, however, on only two experiments and is not substantiated by the results of 13 analyses reported in Table 4 below. These later

[a] Bull., Bureau of Fisheries, vol. XXXV, 1915–16, pp. 155–161.

experiments were made with very careful technique. The oyster meats were dried at low temperature—some of them in vacuum desiccators—to constant weight and the ether used for extraction was rendered anhydrous by distillation over sodium immediately before use. The seeming increase of fat reported for one of the earlier experiments may have been due to the difficulty in maintaining ether in an anhydrous condition in the moist atmosphere of Woods Hole where the analysis was made. The results given in Table 4 do not show in the amounts of ether extract obtained any regularity or any relationship to glycogen. A number of other fat determinations on oysters have been made during the progress of this work. These are not included in this table because glycogen was not determined on the same specimens. In no case, however, did the ether extract amount to more than 3.50 per cent of the dried meats. A series of analyses reported by Atwater [a] gives higher figures, ranging from 6.50 to 10.97 per cent, with an average of 8.78 per cent for 34 analyses. As those determinations were not made with the use of anhydrous ether, they are hardly comparable with the ones reported in this investigation.

TABLE 4.—COMPARISON OF THE GLYCOGEN AND FAT CONTENT OF OYSTER MEATS.

Experiment No.	Glycogen in ash-free solids.	Fat (ether extract) in dried meats.	Fat in ash-free solids.	Experiment No.	Glycogen in ash-free solids.	Fat (ether extract) in dried meats.	Fat in ash-free solids.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	22.46	2.90	3.51	21	7.63	2.33	3.51
2	21.76	3.16	3.91	22	7.38	2.26	3.44
8	14.22	2.04	3.16	27	6.40	1.41	2.15
11	13.51	1.51	2.28	28	6.23	2.85	4.11
19	8.94	2.93	4.32	29	5.88	1.72	2.72
20	8.83	1.19	1.71	31	5.59	1.47	2.15
				34	9.20	1.70	2.60

The oysters showing the high glycogen content were the ones which presented a "fat" appearance. Indeed, the two specimens yielding the highest glycogen figures were selected for analysis by practical oystermen and chosen from beds of oysters deemed to be in the best marketable condition. The conclusion that glycogen is the real nature of the "fat" does not rest alone on the results recorded in the preceding tables. During the past two years glycogen determinations have been made on many samples of oysters in connection with this work. However, only those for which ash and either nitrogen or fat, or both, have been determined also are tabulated here. Of the other specimens it has been noticeable that the higher the glycogen the "fatter" the oysters appeared. Six samples from Lynnhaven Bay, Va., and Narragansett Bay, R. I., considered by the trade to be in good marketable condition, contained glycogen varying from 15.5 to 22.8 per cent of the dried weight and from 20 to 27.9 per cent of the ash-free solids.

DISTRIBUTION OF GLYCOGEN.

The distribution of glycogen in the bodies of oysters of average "fatness" was investigated. About 50 oysters were opened immediately after removal from the water, about September 15, when glycogen formation is rapid. All the juice was drained off

[a] Atwater, W. O.: "The chemical composition and nutritive value of food fishes and aquatic invertebrates," Report of United States Commission of Fish and Fisheries, 1888, pp. 679–868.

from the shell contents and evaporated to dryness. The gills and mantles were dissected off from each meat, mixed together, dried, and ground. Similarly, the adductor muscle was separated and prepared. The remainder, or body, of the oyster containing the liver, digestive system, etc., was dried and ground into one preparation. Glycogen determinations on the four parts of the oyster thus obtained are reported in Table 5. These show little or no tendency for glycogen to diffuse out into the shell liquor of the oyster, and indicate that like higher animals oysters can store glycogen in all tissues but more especially in the liver, for the so-called liver is the chief organ in the part designated as the body of the oyster.

TABLE 5.—DISTRIBUTION OF GLYCOGEN IN OYSTERS.

Parts.	Glycogen in dried substance.	Ash in dried substance.	Glycogen in ash-free solids.
	Per cent.	*Per cent.*	*Per cent.*
Body	27.60	12.71	31.61
Gills and mantles	12.69	18.31	15.53
Muscle	8.51	10.77	9.53
Oyster liquid	(a)	71.6	.....

[a] Too low to be accurately determined.

CONCLUSIONS.

1. Protein and fat do not accumulate in oysters when they attain the condition known as "fat." This is in marked contrast to the accumulation of glycogen which must be regarded as the chief storage substance for oysters. "Fat" oysters are glycogen-rich oysters. Investigations and practical procedures looking to improvements in marketable value of oysters must take into account the importance of those nutritive conditions favoring glycogen formation.

2. The glycogen storage occurs more or less in all tissues of the oysters but is especially prominent in the region of the liver.